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2.	Patent application number *(The Patent Office will fill in this part)*	0308729.3
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	H-Empower Corp 3rd Floor Trade Winds Building Bay Street Nassau Bahamas
	Patents ADP number *(if you know it)*	8611386001
	If the applicant is a corporate body, give country/state of incorporation	Bahamas
4.	Title of the invention	An Integrated Renewable Energy System
5.	Name of your agent *(if you have one)*	Frank B. Dehn & Co.
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	179 Queen Victoria Street London EC4V 4EL
	Patents ADP number *(if you know it)*	166001
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of filing *(day / month / year)*
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An Integrated Renewable Energy System

The present invention relates to a method of using a compression ignition engine in an integrated renewable energy system, whereby the engine is used to drive either an AC electrical generator to produce 'green' electricity for local use or a DC electrical generator to supply the electric current needed to electrolyse water into hydrogen and oxygen.

Compression ignition engines are fuel efficient and diesel engines are therefore widely used for the generation of electricity as well as for transport purposes. Because diesel engines are also mechanically rugged and reliable, diesel engines are one of the most common methods employed to generate local supplies of electricity, particularly in remote, rural or island economies that do not have access to grid supplies of electricity.

Compression ignition engines tend to be fuel specific because they have primarily been designed to burn petroleum fuel oils, such as diesel gas oil, medium fuel oil and heavy fuel oil, which are specially formulated for this type of engine. A readily available and plentiful supply of petroleum fuel oil is therefore required if diesel engines are to be used for power generation purposes. However, in developing countries and in remote locations, such as rural and island economies, petroleum fuel oil can be a relatively expensive commodity and the supply chain to such locations may also be difficult.

Fossil based petroleum fuel oils are in any case finite energy resources, and there is also increasing concern that the emissions released into the atmosphere during the combustion of petroleum fuel oils are causing serious damage to the environment.

For example, the carbon element in petroleum fuel oils burns to form carbon dioxide, a greenhouse gas, and it is now widely accepted that the build-up of carbon dioxide in the atmosphere is contributing towards global warming. In contrast, the hydrogen element in hydrocarbon fuel oils is clean burning because water is the only product produced by the combustion of hydrogen. This is illustrated in the following combustion equation, which uses pentane, an alkane hydrocarbon, as an example of petroleum fuel oil.

$$C_5H_{12} + 8O_2 = 5CO_2 + 6H_2O$$

Other environmental pollutants, including carbon monoxide, volatile organic compounds and sooty particulates, are produced when petroleum fuel oils burn incompletely in an engine, and these substances can also damage the environment and harm human health.

Acid gases, which cause environmental pollution and pose risks to human health, can also be produced during combustion in an engine. For example, nitrogen oxides (NOx) are produced by the reaction of nitrogen and oxygen at high temperatures, and sulphur dioxide (SO_2) and hydrogen chloride (HCl) are produced by the combustion of sulphur or chlorine compounds present in petroleum fuel oils.

Attempts are being made to make petroleum fuel oils less polluting by improving the specification of the oils. For example, the quantity of sulphur permitted in petroleum fuel oils is gradually being lowered in order to reduce the amount of SO_2 released into the atmosphere from reciprocating engines.

Environmental regulations are also becoming more stringent and exhaust gas abatement systems are now an essential element in helping to reduce the release of pollutant emissions into the environment. However, even with the introduction of improved fuel quality and emission controls, the combustion of petroleum fuel oils by reciprocating engines is still one of the major sources of environmental pollution throughout the world.

The present invention seeks to provide ways of using a standard compression ignition engine as an integral part of a renewable energy system, so that the benefits associated with a diesel engine, i.e. its fuel efficiency and mechanical reliability, can be fully exploited whilst simultaneously reducing environmental pollution from the engine.

For example, if compression ignition engines were able to efficiently burn non-fossil fuels, the carbon dioxide produced by the combustion process would not directly contribute towards global warming. Alternatively, if the power generated by a compression ignition engine burning fossil fuel could be used to produce an alternative renewable non-fossil fuel, then the subsequent clean combustion of the renewable fuel would help to off-set the emissions released from the engine when it had been burning the fossil fuel.

By utilising a compression ignition engine in such a flexible way, the engine could become an essential part of an integrated low carbon renewable energy system. For example, the engine could be used to generate 'green' electricity from a non-fossil fuel, or the engine could use either a fossil or a non-fossil fuel to generate the power required to produce an alternative clean burning renewable fuel. Preferably the alternative renewable fuel should be capable of being used in the integrated renewable energy system itself, either as a fuel for local power generation or as a fuel for local transport applications.

From a first broad aspect therefore the invention provides a method of using a compression ignition engine in a renewable energy system, wherein a diesel engine genset would be able to burn either fossil or non-fossil liquid fuels in a clean and efficient manner, and at least part of the electricity generated by the diesel engine genset would then be used to produce an alternative form of renewable non-fossil fuel that could also be used in the integrated renewable energy system.

It is a well-established fact that non-fossil liquid fuels burn poorly in standard compression ignition engines. For example, non-fossil liquid biofuels tend to produce combustion deposits inside the engine and the exhaust smoke emitted from the engine is usually black and heavily polluted with carbon monoxide and sooty particulates.

However, research by the applicant has shown that non-fossil liquid biofuels, including vegetable oils, animal fats, fish oils, natural alcohol and mixtures of such materials, can be burned efficiently and cleanly in a standard compression ignition engine by enriching the combustion atmosphere inside the combustion chambers of the engine with oxygen.

Liquid biofuels are either derived directly from plants or from animals that live on plants, and as plants absorb carbon dioxide from the atmosphere during their natural growing cycle, biofuels are a renewable and sustainable source of energy.

A further benefit of oxygen enrichment is that it significantly improves the efficiency of the engine combustion process and ensures that fuels are burned much more completely than under normal naturally aspirated combustion conditions. The emissions of pollutants that are produced by incomplete combustion, i.e. carbon monoxide, volatile organic compounds and particulates, are therefore much reduced under enriched oxygen combustion conditions.

This is illustrated in Table 1, which compares the normal naturally aspirated combustion of diesel gas oil in a compression ignition engine with the enriched oxygen combustion of tallow animal fat and a vegetable oil in the same engine. For ease of comparison, the emissions in Table 1 are expressed as values relative to those obtained during the normal combustion of diesel gas oil.

As shown in Table 1, the emissions of carbon monoxide and particulates are much reduced when an enriched oxygen atmosphere is used in the engine; however, nitrogen oxide (NOx) emissions are higher because of the greater concentration of oxygen in the combustion chamber of the engine. Fortunately, NOx in the engine exhaust gas is easily abated by means of catalytic reduction with either ammonia or urea.

Table 1
Combustion of diesel gas oil, tallow and vegetable oil
Relative exhaust gas emissions

Emission Relative Values	Diesel Gas Oil Naturally Aspirated	Tallow Animal Fat Enriched Oxygen	Vegetable Oil Enriched Oxygen
Power	1.0	1.0	1.0
Carbon monoxide	1.0	0.23	0.32
NOx unabated	1.0	2.64	2.70
NOx abated	1.0	0.45	0.37
Particulates	1.0	<0.1	<0.1

Oxygen enrichment improves the combustion of all liquid engine fuels, and fossil petroleum based fuel oils therefore also burn much better in an enriched oxygen combustion atmosphere. For example, enriched oxygen combustion would ensure that petroleum fuel oils burned more efficiently and more completely in an engine. Although the carbon dioxide released from the combustion process would still have a greenhouse gas impact in the atmosphere, because it had been derived from a fossil fuel, the emissions of other combustion pollutants, such as carbon monoxide, volatile organics and particulates, would be significantly reduced.

From a further aspect therefore the invention provides a method of using a compression ignition engine as an integral part of a renewable energy system, whereby an enriched oxygen combustion atmosphere would be used in the combustion chambers of the engine so that the engine had the capability of being able to burn either fossil or non-fossil liquid fuels in a clean and efficient manner.

The enriched oxygen air for the combustion process could, for example, be produced by a gas separation membrane system, which separates normal air into an oxygen rich fraction and a nitrogen rich fraction.

Alternatively, for some applications it may be more convenient to produce the enriched oxygen atmosphere by adding pure oxygen to normal air. Unfortunately, the pure oxygen supplied by industrial gas manufacturers, either in the form of a compressed gas or a liquid, is expensive and the high cost of the oxygen could well influence the viability of the combustion process.

Oxygen can also be produced by various industrial processes, including pressure swing absorption, vacuum swing absorption and cryogenic systems; however, these methods of oxygen production are both energy and capital intensive.

However, oxygen can also be produced by the electrolysis of water, and in the context of an integrated renewable energy system, water electrolysis is a particularly interesting process because it also produces hydrogen, a clean burning, renewable and totally sustainable source of energy, as well as oxygen.

For example, when hydrogen burns it recombines with oxygen to form water, and hydrogen is therefore a unique energy resource because, in theory, this cycle of converting water to hydrogen and then combusting the hydrogen to form more water could be repeated endlessly.

In contrast to fossil fuels, which always produce carbon dioxide during their combustion, innocuous water is the only product of combustion when hydrogen is burned. Hydrogen is therefore an ideal sustainable fuel to use in a fully integrated renewable energy system.

The water to hydrogen to water cycle is illustrated by the following reactions:

Electrolysis of water: $2H_2O = 2H_2 + O_2$

Combustion of hydrogen: $2H_2 + O_2 = 2H_2O$

Because hydrogen is an exceptionally clean burning fuel, there is increasing interest in developing hydrogen as a potential renewable energy resource, particularly for transport applications where the environmental pollution from reciprocating engines burning petroleum fuels is now causing worldwide concern.

The hydrogen and oxygen produced by the electrolysis of water can also be utilised together as reactants in a fuel cell to produce 'green' electricity. Fuel cells convert chemical energy into electrical energy, and unlike batteries, which only store electricity and can run down, fuel cells will continue to operate at a constant power output as long as there is a supply of hydrogen and oxygen. Fuel cells have potential for transport applications as well as for power generation, although the future use of fuel cells on a large scale will be dependent on having a readily available, cost effective supply of hydrogen and oxygen.

Hydrogen is therefore a unique energy resource because it can be used in a number of different ways to power transport vehicles. For example, hydrogen could be used as a compressed gaseous fuel for an engine, or as a reactant, along with oxygen, in fuel cells to power a vehicle by electricity, or as a fuel in hybrid vehicles that combine both an engine and fuel cells. Whichever way the hydrogen was used as a transport fuel, virtually no pollutants would be released into the atmosphere from the vehicle.

Water electrolysis is a well known process. For example, when two oppositely charged electrodes are inserted into water and a current is passed between them, electrons are transferred from the anode to the cathode.

As the electric current passes through the water, the chemical bond between hydrogen and oxygen breaks down to produce two positively charged hydrogen ions and one negatively charged oxygen ion. The negative oxygen ions then migrate to the positive electrode (the anode) and the positive hydrogen ions are attracted to the negative electrode (the cathode).

The smallest amount of energy needed to electrolyse one mole of water into hydrogen and oxygen is 65.3 Wh at 25°C, and when hydrogen and oxygen recombine by combustion back into water 79.3 Wh of energy is released. 14 Wh more energy is therefore released during the combustion of hydrogen than is needed to split water into hydrogen and oxygen.

The electrical resistance of pure water is high at 100 ohm/cm, and to encourage electrolysis the electrical resistance is usually lowered by the addition of heat; pressure; a salt to the water; an acid to the water; an alkali to the water; or a suitable combination of such variables.

By way of example, a low pressure commercial water electrolyser may well typically operate under normal ambient atmospheric pressure and at a temperature of about 70°C, and use an electrolyte consisting of 25% to 30% potassium hydroxide solution.

An electrolysis cell primarily consists of a pair of electrodes immersed into a container of electrolyte, and a water electrolysis unit is composed of a large number of electrolysis cells combined together, either in series and/or in parallel, to provide a greater output of hydrogen and oxygen.

Water electrolysis is, however, an unusual electrical process in so far as it requires a low voltage but very high direct electric current. A voltage of only 1 to 2 volts is needed to electrolyse water and depending on the efficiency of the electrolysis system the energy input required to electrolyse water is approximately 4 kWh/m^3 of hydrogen produced.

Although the voltage required to effect water electrolysis remains fairly constant, water will electrolyse under varying levels of current. For example, commercially available electrolysis units operate with currents varying from about 1500 amps/m^2 up to 5000 amps/m^2 or more. The volume of hydrogen produced by the electrolysis process is, however, related to the current, i.e. the higher the current, the more efficient the electrolysis process tends to be.

Although water itself is cheap, abundant and readily available, the water electrolysis process is energy intensive and also requires a specific supply of low voltage, high direct current.

If conventional grid electricity is used to power a water electrolysis process, the normal high voltage alternating grid electric current has to be converted into low voltage direct current, i.e. from AC to DC electricity.

Such radical current commutation requires expensive transformers and rectifiers, and significant current losses can also occur during the current conversion process. A further disadvantage of using grid electricity to electrolyse water is that a large part of the electricity supplied to many national grid networks will probably have been generated from the combustion of coal, the most polluting of the carbon based fossil fuels.

An alternative to transforming normal grid AC current to DC current would be to use a DC generator to produce the low voltage, high direct current needed to for water electrolysis, and such a current can be produced by means of a homopolar generator.

From a further aspect, the invention uses an enriched oxygen combustion atmosphere in a compression ignition engine, so that the engine can burn either fossil or non-fossil liquid fuels in a clean and efficient manner, and the engine is used in an integrated renewable energy system to drive either an AC generator to produce electricity for local use or a DC homopolar generator to produce the direct current needed to electrolyse water into hydrogen and oxygen. Hydrogen from the water electrolysis process is a valuable renewable energy resource, whilst oxygen from the water electrolysis process can be used to produce the enriched oxygen atmosphere for the engine. Hydrogen and oxygen from the water electrolysis process can also be utilised together as reactants in fuel cells to produce electricity.

The principles of homopolar generation were originally established by Faraday who found that when a conductive disc was rotated through a magnetic field, a voltage was generated between the centre of the disc and the outer rim of the disc.

Homopolar machines produce a unidirectional electromotive force, and homopolar generators are unique in that they produce low voltage but high direct current. Because the current produced by a homopolar generator is low voltage, homopolar generation is also a relatively safe method of generating and transmitting electricity.

Figure 1 is a schematic cross-section illustration of a simple homopolar generator, based on the principles first described by Faraday.

In Figure 1, a shaft 3 runs through the centre of both poles of a magnet 2, and in a m anner whereby shaft 3 can freely rotate within the magnet 2. A metal disc 1 is fixed to shaft 3 and is spatially arranged so that the metal disc 1 is centrally located between the north and south poles of the magnet 2.

Rotation of shaft 3, by the application of an external rotating force, correspondingly rotates the metal disc 1 between the poles of the magnet 2, so that the disc intersects the magnetic field produced by the magnet.

Rotation of disc 1 in the magnetic field generates a voltage between the centre of the disc and the rim of the disc. An electric charge, which can be collected by electrical contact brushes placed at the rim and at the centre of the disc, is produced in disc 1.

The efficiency of a homopolar generator is greatly improved if an annular magnetic field, whose axis passes through the centre of the drive shaft, is used in the system. When an annular magnetic field is used, the electromotive force developed in any ring is constant so that all current paths in the disc are radially orientated.

Improvements in the performance of homopolar generators have tended to concentrate on utilising as much of the available magnetic field as possible. Particular emphasis has been placed on the shape and position of the magnets used in homopolar machines and also on the relative spatial arrangement of the magnets and the conductive disc.

Another refinement to homopolar machines has involved the use of superconducting electromagnetic coils. Superconducting coils are able to produce high magnetic fields, which is beneficial for efficient homopolar machine operation. However, to perform effectively most superconducting materials have to be used at extremely low temperatures, i.e. temperatures at or close to cryogenic temperatures, and the need to maintain such low temperature operating conditions does have an affect on the capital and operating costs of the homopolar machine.

The magnetic field produced by an annular magnet or an annular electromagnetic coil has an axis of rotational symmetry and the field is toroidal in character. Lines of magnetic flux emanate from the centre of the magnet or coil and initially flow outwards in a forward direction. The magnetic flux then moves in a circular toroidal manner until the magnetic flux eventually returns back to the rear of the magnet or coil.

Homopolar machines were originally designed with the conductive disc positioned so that the disc only intersected the magnetic field travelling in a forward direction, as illustrated in the basic homopolar machine shown in Figure 1. The performance of a homopolar generator can be improved if both the forward and the return magnetic fields produced by a magnet or a coil are utilised to generate current in the disc.

Figure 2 is a schematic cross-sectional illustration of a typical homopolar generator that has been designed to enable the conductive disc to intersect both the forward and the return magnetic fields produced by an electromagnetic coil.

In Figure 2, the metal conductive disc 5, which is attached to a drive shaft 6, and the annular electromagnetic coil 7 are together referred to as the homopolar generator 4.
The annular electromagnetic coil 7 is composed of many turns of either conducting material or more preferably superconducting material. When a current passes through coil 7, a toroidal magnetic field 12, comprising a forward field 10 and a return field 11, is generated about an axis of rotational symmetry 9.
For ease of illustration, only one magnetic line of flux 12 with a forward field 10 and a return field 11 is shown in Figure 2. Diagrammatic lines of flux are a pictorial device used to illustrate a magnetic field, and a true representation of the magnetic field generated by coil 7 would entail an infinite number of lines of flux completely surrounding the annular coil 7.
A thin and substantially flat conductive metal disc 5 is connected centrally to a shaft 6 in a manner whereby rotation of shaft 6, by an external rotary motive force, would also rotate disc 5 about a central axis that is perpendicular to the disc whilst being simultaneously coincident with the central axis 9 of the magnetic field. The disc 5 is positioned so that the bottom surface of the disc is in close proximity to the annular coil 7.
The metal disc 5 and the annular coil 7 are spatially arranged so that the forward magnetic field 10 passes through the central portion of disc 5, whilst the return magnetic field 11 passes through the outer portion of disc 5. The central portion of disc 5, which is subjected to the forward magnetic field 10, is separated from the outer portion of disc 5, which is subjected to the return magnetic field 11, by a ring of insulating material 13. The ring of insulating material 13 runs radially around the disc 5 at a fixed distance from the centre of the disc
When disc 5 is rotated through the toroidal magnetic field, the currents generated in the inner and outer portions of the disc 5, which are subjected to the forward and reverse magnetic fields respectively, flow in opposite directions in the two portions of the disc.
In this particular embodiment of a homopolar generator, the annular coil 7 is surrounded by a core 8 of highly permeable magnetic material such as soft iron. The iron core 8 further concentrates the return magnetic field 11 towards coil 7, so that more of the return field passes through the outer region of disc 5, thus allowing disc 5 to utilise more of the magnetic field produced by the annular coil 7.
A slide arm mechanism 15 is fixed in position above the top surface of the conductive disc 5, and in a manner whereby the slide arm 15 extends from the centre to the outside of the disc.

For example, the inner end of slide arm 15 is in close proximity to drive shaft 6, whilst the outer end of slide arm 15 extends over the outer rim of disc 5. Electrical current contact brushes 16, 18 and 19 are located on the underside of slide arm 15.

Brush 16 collects the current produced on the central portion of disc 5. An interconnecting slide arrangement between arm 15 and brush 16 allows the position of brush 16, relative to the top surface of disc 5, to be adjusted by sliding brush 13 along arm 15 until the brush is at the required position on the inner portion of disc 5.

Brush 18 collects the current produced on the outer portion of disc 5. An interconnecting slide arrangement between arm 15 and brush 18 allows the position of brush 18, relative to the top surface of disc 5, to be adjusted by sliding brush 18 along arm 15 until the brush is at the required position on the outer portion of disc 5.

This arrangement allows fine adjustment of the contact brushes 16 and 18, until the brushes are at the point of optimum current on the inner and outer portions respectively of the conductive disc 5. The contact brushes 16 and 18 can then be locked in place on the slide arm 15 by using interlocking fixings mounted on the brushes and the slide arm respectively.

It is essential that brushes 16 and 18 make good contact with the top surface of disc 5, in order to allow efficient collection of the electric current generated by the homopolar machine.

To help provide good conducting properties between the contact brushes 16 and 18 and disc 5, a liquid metal contact material could be used on the surface of the disc, and such liquid metal conducting materials are described in US Patent Number 5281364 by the applicant.

Another current contact brush 14 makes contact with the drive shaft 6, and a further contact brush 19 mounted under the outer end of slide arm 15 makes contact with the outer rim of disc 5. Again it is essential that good electrical contact is made by brushes 14 and 19 with the drive shaft and the outer rim of the disc respectively.

Rotation of shaft 6 by an external motive force rotates disc 5 through the toroidal magnetic field produced by the annular coil 7. This in turn generates electric currents in the inner and outer portions of disc 5, which are collected by contact brushes 16 and 18.

Brush 16 and brush 14 are connected to an electrical circuit 17, and brush 18 and brush 19 are connected to an electrical circuit 20. The two circuits 17 and 20 are connected together, either in series or in parallel, before the combined current is finally transmitted from the homopolar generator to the water electrolysis unit. Means to measure and control the current can be included in the electric circuit that takes the current from the homopolar generator to the water electrolysis unit.

Homopolar generators are compact machines and they can easily be connected together in multiple combinations, either in series and/or in parallel, to produce sufficient current to be able to run similar multiple combinations of water electrolysis units, which would also be connected together either in series and/or in parallel.

Developments in the design of homopolar machines, superconducting materials and current collection systems have resulted in homopolar generators becoming much more efficient. For example, it is not unknown for homopolar generators to have an efficiency of over 99%.

A homopolar generator is therefore an effective method of directly supplying the low voltage, high current needed to operate a water electrolysis unit. Apart from relatively simple means to measure and control the current, no other sophisticated commutation equipment, such as expensive and inefficient transformers and rectifiers, would be required to alter the current before it was supplied to the water electrolysis unit.

Using an enriched oxygen compression ignition engine to drive the homopolar generator also provides flexibility because oxygen enrichment allows the engine to combust whatever liquid fuels, of either fossil or non-fossil origin, are available locally.

For example, oxygen enrichment would allow locally available biofuels, such as vegetable oils, to be burned efficiently in an engine, as well as petroleum fuel oils. In tropical countries this would allow palm oil and coconut oil to be used as fuel, whilst groundnut oil could be used in sub-tropical regions, and rapeseed oil, sunflower oil and soybean oil could be used in temperate zones. Animal fats and waste cooking oil could also be used as biofuels in an enriched oxygen diesel engine, as could natural alcohol fermented from locally grown sugar or starch producing plants.

This provides a high degree of flexibility for the integrated renewable energy system. For example, during the day the engine could be run on say locally available non-fossil biofuels to generate AC 'green' electricity for local supply, whilst during the night the engine could be run on either biofuel or petroleum fuel oil to generate the DC electricity required for the electrolysis of water.

When a non-fossil biofuel is used in the engine to produce hydrogen by water electrolysis, the carbon dioxide released into the atmosphere from the engine does not have a greenhouse gas impact on the environment. In contrast, the most widely used industrial method of manufacturing hydrogen, i.e. the steam reforming of natural gas, uses a finite, fossil based raw material and the process therefore produces greenhouse carbon dioxide.

A further benefit of the proposed system is that when a fossil fuel, such as petroleum fuel oil, is used in the engine, it provides a method of converting the hydrocarbon based fuel oil into valuable hydrogen and oxygen on a scale that is not only practical but also specifically related to local requirements for renewable energy.

Both the oxygen and the hydrogen from the water electrolysis process would have applications in the integrated renewable energy system. The oxygen could be used to produce the enriched oxygen combustion atmosphere for the engine, whilst hydrogen could be used as either a clean burning renewable gaseous fuel or as a reactant, along with oxygen, in fuel cells to produce 'green' electricity.

The integrated renewable energy system will now be described with reference to illustrations given in Figures 3 and 4, where;

Figure 3 is schematic illustration of a diesel engine generating system capable of producing either AC electricity for local supply or DC electricity for a water electrolysis unit.

Figure 4 is a schematic illustration of the exhaust gas abatement system that may be required for an engine combusting a variety of fossil and non-fossil fuels.

In Figure 3, a compression ignition engine 17 has a drive shaft coupled to both an AC electrical generator 18 and a DC homopolar generator 19. In practice the homopolar generator 19 would consist of a multiple combination of homopolar generators, connected together either in series and/or in parallel, to produce sufficient current to be able to run a similar multiple combination of water electrolysis units.

Liquid fuels for the compression ignition engine would be stored in a number of fuel storage tanks 20, although only one fuel tank is shown in Figure 3. The fuels could be either fossil fuel oils, such as petroleum fuel oils and waste mineral oils, or non-fossil biofuels, such as vegetable oils, animal fats, fish oils, natural alcohol, waste biofuels, waste cooking oil and mixtures of such materials.

Fuel from storage tank 20 would be heated and filtered, as necessary, before being transferred to the fuel injectors of engine 17. The fuel injectors would inject fuel at the appropriate time into the combustion chambers of the engine.

The oxygen rich air that comprises the combustion atmosphere of the engine would be prepared by mixing pure oxygen from storage tank 21 with normal atmospheric air, using a mixing valve 22 that would also continually analyse the composition of the enriched oxygen air.

For example, the enriched oxygen air would usually contain between 2% and 6% extra oxygen, i.e. the enriched oxygen air would typically have a composition of between 23% oxygen, 77% nitrogen and 27% oxygen, 73% nitrogen, depending on how difficult the fuel was to burn in a compression ignition engine. Fuels that are very difficult to burn in an engine may well need even more than 6% extra oxygen in the combustion atmosphere of the engine.

The oxygen rich air would be introduced into a cylinder inside the engine through the air inlet valve, and the air would then be compressed by a piston travelling up the cylinder. A fuel injector would inject fuel into the combustion chamber of the cylinder, and the fuel would ignite by the heat of compression. The piston would then be forced back down cylinder.

The motion of the pistons up and down the cylinders in the engine would be transferred as a rotary motion to the drive shaft of the engine, and the drive shaft would be coupled to both an AC generator 18 and a homopolar generator 19. The drive shaft would be capable of being readily engaged to or disengaged from the AC generator 18 and the DC homopolar generator 19 respectively, so that the drive shaft would only be coupled to one generator at a time.

When driving the AC generator 18, the AC electricity produced by the genset would be supplied to an electric circuit that would distribute the electricity to meet local demands. Preferably a non-fossil biofuel would be used when generating the AC electricity so that 'green' electricity was produced for local use.

When driving the homopolar generator 19, the DC electricity produced by the genset would be supplied by an electric circuit to a water electrolysis unit 23. Either non-fossil biofuel or fossil petroleum fuel could be used to generate the DC electricity.

The current from a single homopolar generator would typically have a voltage of about 2 volts and a power density of about 5000 amps/m^2 or more, whilst the energy consumption of a typical electrolysis unit would be about 4 kWh/m^3 of hydrogen produced.

For ease of illustration, the water electrolysis unit 23 in Figure 3 consists of only four electrolysis cells. In practice, a commercial electrolysis unit may well contain several hundred electrolysis cells, and a typical electrolysis unit could have an hourly output of over 400m^3 of hydrogen and over 200m^3 of oxygen.

By combining a number of homopolar generators together, in series and/or in parallel as appropriate, sufficient current could be produced to be able to operate a similar multiple combination of electrolysis units, also connected together either in series and/or in parallel, in order to meet the specific demands for hydrogen and oxygen.

The electrolysis unit illustrated in Figure 3 is a schematic representation of a typical low temperature, low pressure electrolysis system, of the type manufactured, for example, by Norske Hydro.

Each cell would have a cathode 24, made from say low carbon steel, and an anode 25, made from say nickel plated low carbon steel.

The electrolyte in each cell would typically be a 25 % solution of potassium hydroxide, and there would be means to continually replenish the cells with fresh water. Application of the electric current produced by the homopolar generator 19 to the electrolysis cells produces hydrogen at the cathodes of the cells and oxygen at the anodes.

In order to keep the hydrogen and oxygen separate from each other, each cell would include a separator 26 manufactured, for example, from woven asbestos cloth.

Hydrogen from the cathodes of the cells is collected in a discharge tube, which would deliver the hydrogen to a packaging plant (not shown in Figure 3) where the hydrogen would either be compressed and packed into cylinders or be liquefied and packed into tanks.

Oxygen from the anodes is collected in a separate discharge tube 30 and the oxygen is delivered to storage tanks 21, although only one storage tank is illustrated in Figure 3.

The oxygen cycle in the integrated energy system would then be complete, because oxygen from tank 21 would be used to produce the enriched oxygen combustion atmosphere for the engine 17 that powers the system. Excess oxygen in tanks 21 would be delivered to a packaging plant (not shown in Figure 3) where the oxygen would either be compressed and packed into cylinders or be liquefied and packed into tanks.

In the integrated renewable energy system illustrated in Figure 3, oxygen enrichment would enable the compression ignition engine 17 to burn a variety of fossil and non-fossil fuel oils. The exhaust gas from the engine would therefore need to be cleaned to an appropriate degree before the exhaust gas was released to the atmosphere, and the abatement required would mainly be dependent on the type of fuel being burned in the engine.

A typical engine abatement system is described in Figure 4. In Figure 4, the compression ignition engine 17 is again coupled to the AC generator 18 and the DC homopolar generator 19. Fuels are stored in fuel tanks 20, although only one tank is shown in Figure 4, and an enriched oxygen combustion atmosphere is supplied to the engine.

The condition of the exhaust gas emitted from engine 17 will be dependent on the particular fuel being burned in the engine.

For example, the exhaust gas from the enriched-oxygen combustion of either a good quality low sulphur petroleum gas oil or a virgin non-fossil biofuel would contain very little carbon monoxide, volatile organic compounds, sulphur dioxide, heavy metals or particulates. In this instance, NOx abatement with urea by a catalytic reduction unit 27 would probably be the only treatment required before the exhaust gas was in a suitable state to be released to the atmosphere through the chimney 33.

Other petroleum based fuel oils, such as medium and heavy fuel oils, can contain sulphur and particulate material, and these particular fuel oils are also more difficult to burn than gas oil, even with oxygen enrichment. The exhaust gas from the enriched oxygen combustion of medium/heavy fuel oil would therefore definitely need NOx abatement in catalytic reduction unit 27 and probably filtration in filter 32 to remove particulates.

Further abatement will depend on an analysis of the exhaust gas, and could possibly include catalytic oxidation in unit 28, to reduce carbon monoxide and volatile organic compounds, and acid gas neutralisation in unit 31.

The combustion of waste based fuels, including waste mineral oil and waste cooking oil, is becoming much more strictly controlled, and very stringent emissions limits are being imposed on waste combustion processes under regulations such as the EU Waste Incineration Directive. When burning waste based fuels, and particularly waste mineral oils, the exhaust gas from the engine would probably therefore need full emission abatement, i.e. de-NOx in unit 27, catalytic oxidation in unit 28, neutralisation in unit 31 and filtration in unit 32.

The engine combustion system illustrated in Figure 4 is a combined heat and power (CHP) process where the exhaust gas passes through a boiler 29 in order to recover the waste heat in the exhaust gas. The steam from boiler 29 could be used to drive a steam turbine 30, which would produce more AC electricity for local use, and/or the steam could be used for local heating. The size of the compression engine, and hence the amount of heat available in the engine exhaust, would determine whether or not a steam boiler in the exhaust would be a practical proposition. Heat is also available from the engine cooling system and this source of waste heat can also be used for local heating purposes.

The integrated renewable energy system illustrated in Figures 3 and 4, which is based on using a compression ignition engine to generate heat and power for local needs and also to supply the specific current required by a water electrolysis process, can be used in a number of different ways, depending on the fuels available locally.

Because the engine incorporates an enriched oxygen combustion atmosphere, the engine is able to efficiently and cleanly burn locally available fuels of either fossil or non -fossil origin. For example, when burning non-fossil biofuels, the engine can be used to drive an AC electrical generator to produce 'green' electricity for local needs, and the waste heat from the combustion process can also be recovered for local use.

When burning fossil petroleum fuel oils, the engine can be used to drive a DC homopolar generator to produce the current required for the water electrolysis process, whilst the heat produced from the combustion of the petroleum fuel oil can still be recovered for local use.

With full exhaust gas abatement, the system can even be used to safely incinerate waste oils. For example, when burning waste mineral oil the engine can drive the homopolar generator to produce the current required to electrolyse water. The system then acts as a method of converting potentially polluted waste mineral oil into clean burning, renewable hydrogen fuel, whilst the heat from the combustion process can still be recovered for local use.

The integrated energy system can therefore produce a number of valuable product streams, including a supply of 'green' electricity from the AC generator when non-fossil biofuels are combusted in the engine, a supply of valuable hydrogen and oxygen from the water electrolysis process, and a supply of heat from the engine combustion process.

Both the hydrogen and the oxygen produced by the electrolysis of water are valuable products that have potential applications in a variety of end uses. For example, hydrogen is a unique energy resource with particular potential as a clean burning transport fuel, whilst oxygen is already used in a number of industrial applications including combustion processes, chemical processes, aerobic fermentation, water purification and medical uses. Hydrogen and oxygen can also be used together as the reactants in a fuel cell to produce clean, 'green' electricity.

The proposed integrated energy system is especially aimed at supplying local heat and power requirements in a low carbon, energy-efficient manner. Because the integrated energy system is based on being able to burn different fuels of either fossil or non-fossil origin, the system could be of particular benefit for remote locations, such as rural or island economies, as they would no longer need to solely rely on petroleum fuel oils for their local energy requirements.

Transport applications for the hydrogen produced from the system would similarly be aimed at locally based transport systems that could, for example, use specially adapted vehicles for short distance operations, such as local public transport or local distribution services. The vehicles could then be supplied with hydrogen fuel from specialised locally based storage depots.

Claims

1. A method of power production comprising coupling a compression ignition engine to an AC electrical generator and/or to a DC homopolar generator, wherein the homopolar generator produces an electric current which is used to electrolyse water into hydrogen and oxygen.

2. A method as claimed in claim 1, wherein an oxygen enriched combustion atmosphere is provided in the engine, said atmosphere being prepared by mixing pure oxygen, which is produced by the water electrolysis process, with normal atmospheric air.

3. A method as claimed in claim 1 or 2, wherein the oxygen enriched atmosphere contains between 2% and 6% extra oxygen, i.e. the air has a composition of between 23% oxygen, 77% nitrogen and 27% oxygen and 73% nitrogen.

4. A method as claimed in claim 1 or 2, wherein the wherein the oxygen enriched atmosphere contains more than 6% extra oxygen.

5. A method as claimed in any preceding claim, wherein the fuel for the engine is a fossil petroleum fuel oil, such as diesel gas oil, medium fuel oil or heavy fuel oil, or the fuel is a fossil waste based oil, such as recovered fuel oil or waste mineral oil.

6. A method as claimed in any of claims 1 to 4, wherein the fuel for the engine is a non-fossil biofuel such as vegetable oil, animal fat, fish oil, natural alcohol or mixtures of such biofuels, or the fuel is a non-fossil waste based material, such as waste vegetable oil, waste animal fat, waste fish oil, waste alcohol or waste cooking oil.

7. A method as claimed in any preceding claim, wherein the engine is coupled to the AC generator and the DC homopolar generator in such a manner as to be coupled to only one generator at a time.

8. A method as claimed in claim 7, wherein the compression ignition engine is run on a non-fossil biofuel when the engine is used to drive the AC generator.

9. A method as claimed in any preceding claim, wherein the engine is run at a fixed, controlled speed that provides efficient engine performance and optimum power generation.

10. A method as claimed in any preceding claim, wherein the homopolar generator comprises an electromagnetic coil to produce an annular toroidal magnetic field; means to position a conductive metal disc in the toroidal magnetic field so that the disc is intersected by both the forward and the return magnetic fields of the toroidal magnetic field; means to connect the conductive disc to a drive shaft that is rotated by the compression ignition engine; and means to collect electric current generated in the conductive disc when the disc is rotated through the toroidal magnetic field.

11. A method as claimed in claim 10, wherein the DC electricity from the homopolar generator has a voltage of between about 1 and 2 volts and a current of about 5000 amps/m^2 or more.

12. A method as claimed in any preceding claim, wherein the compression ignition engine drives a multiplicity of homopolar generators that are connected together either in series and/or in parallel.

13. A method as claimed in any preceding claim, wherein a single homopolar generator or a multiple combination of homopolar generators is/are connected by an electrical circuit to either a single water electrolysis unit or to a multiple combination of water electrolysis units that are also connected together either in series and/or in parallel.

14. A method as claimed in claim 13, wherein the or a water electrolysis unit is a low pressure, low temperature electrolysis system that operates at about 70°C and under normal ambient atmospheric pressure conditions, and where said water electrolysis unit consists of a large plurality of electrolysis cells each containing an electrolyte comprising a 25% solution of potassium hydroxide.

15. A method as claimed in any preceding claim, wherein the homopolar generator powers a water electrolysis unit and the hydrogen from the water electrolysis process is used as a

renewable fuel, either in the form of a gaseous fuel or as a reactant in a fuel cell, and the oxygen from the water electrolysis unit is used to produce the oxygen enriched combustion atmosphere for the engine, and the oxygen is also, optionally, used as a reactant, along with the hydrogen, in a fuel cell.

16. A method as claimed in any preceding claim, wherein the heat from the combustion process is recovered for local use.

17. A method as claimed in claim 16 wherein heat in the engine exhaust is recovered by using the heat to produce steam in a boiler and using the steam for either local heating purposes or to drive a steam turbine.

18. A method as claimed in claim 16, wherein the heat from the engine cooling system is recovered and used for local heating purposes.

19. A method as claimed in any preceding claim, wherein exhaust gas from the engine is treated, dependent on an analysis of the exhaust gas, so that prescribed pollutants in the exhaust gas are reduced to an acceptable environmental level before the exhaust gas is released into the atmosphere.

20. An energy generating system comprising a compression ignition engine; means to supply an oxygen enriched combustion atmosphere to the combustion chamber(s) of the engine; means to supply liquid fuel of either fossil or non-fossil origin to the combustion chamber(s) of the engine; an AC electrical generator; a DC homopolar electrical generator; means for coupling the engine to either the AC generator or the DC generator; a water electrolysis unit; and means to supply the current from the DC homopolar generator to the water electrolysis unit.

21. A system as claimed in claim 20 further comprising means to use the oxygen produced by the water electrolysis unit to prepare the oxygen enriched combustion atmosphere for the engine.

22. A system as claimed in any of claims 20 or 21, wherein the homopolar generator comprises an electromagnetic coil to produce an annular toroidal magnetic field; means to position a conductive metal disc in the toroidal magnetic field so that the disc is intersected by both the forward and the return magnetic fields of the toroidal magnetic field; means to connect the conductive disc to a drive shaft that is rotated by the compression ignition engine; and means to collect electric current generated in the conductive disc when the disc is rotated through the toroidal magnetic field.

23. A system as claimed in any of claims 20 to 22 wherein the DC electricity from the homopolar generator has a voltage of between about 1 and 2 volts and a current of about 5000 amps/m^2 or more.

24. A system as claimed in any of claims 20 to 23, wherein the compression ignition engine drives a multiplicity of homopolar generators that are connected together either in series and/or in parallel.

25. A system as claimed in any of claims 20 to 24, wherein a single homopolar generator or a multiple combination of homopolar generators is/are connected by an electrical circuit to either a single water electrolysis unit or to a multiple combination of water electrolysis units that are also connected together either in series and/or in parallel.

26. A system as claimed in any of claims 20 to 25, wherein the or a water electrolysis unit is a low pressure, low temperature electrolysis system that operates at about 70°C and under normal ambient atmospheric pressure conditions, and where said water electrolysis unit consists of a large plurality of electrolysis cells each containing an electrolyte comprising a 25% solution of potassium hydroxide.

27. A method of using a compression ignition engine in a renewable energy system, wherein a diesel engine burns either fossil or non-fossil liquid fuels and at least part of the electricity generated by the diesel engine is then used to produce an alternative form of renewable non-fossil fuel.

28. A method of using a compression ignition engine in an integrated renewable energy system, whereby the engine is used to drive either an AC electrical generator to produce electricity or a DC electrical generator to supply the electric current needed to electrolyse water into hydrogen and oxygen.

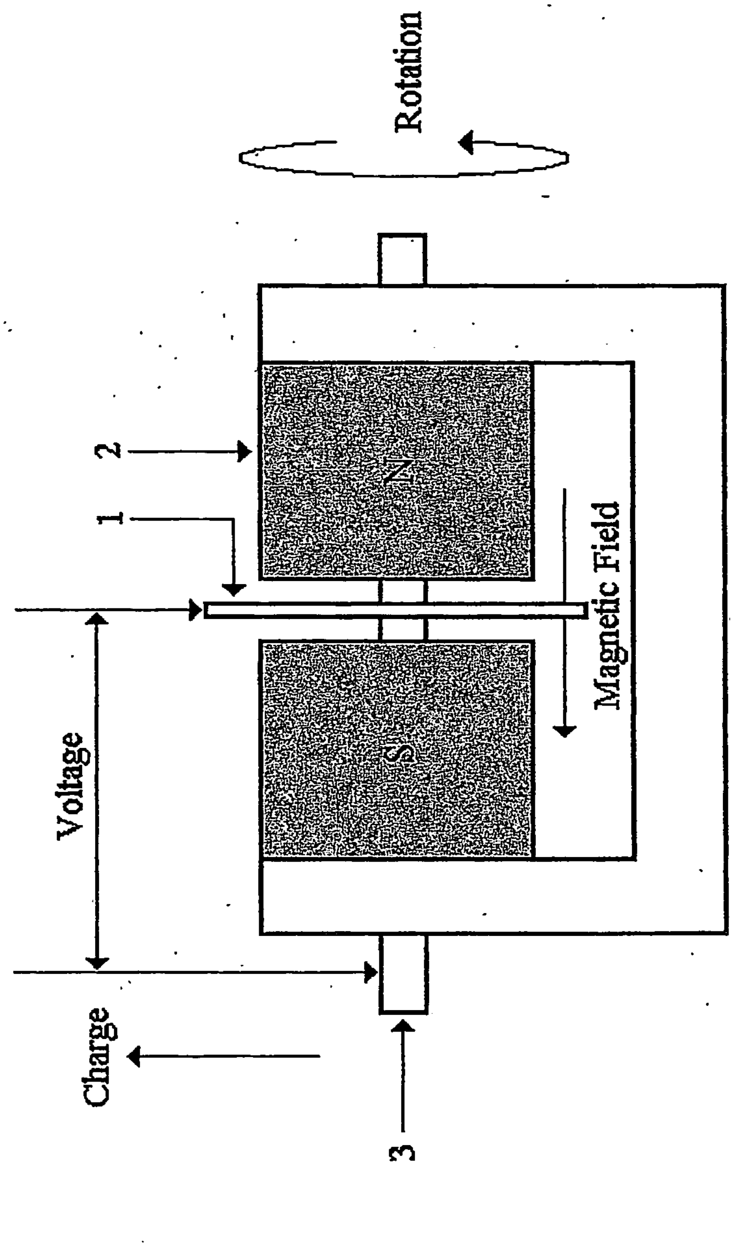
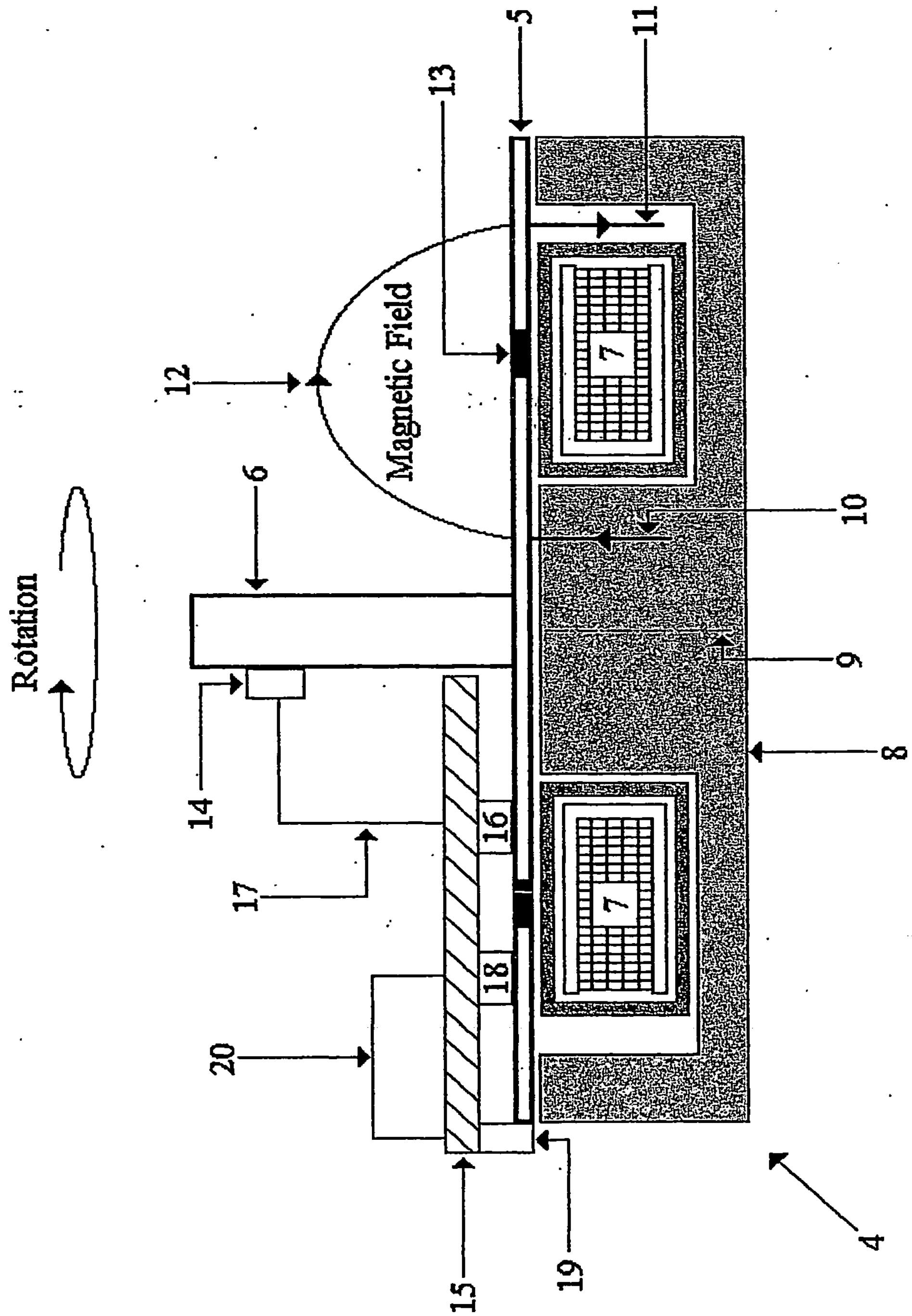


Figure 1



Rotation
Magnetic Field
4
5
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7
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8
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11
12
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19
20

Figure 2

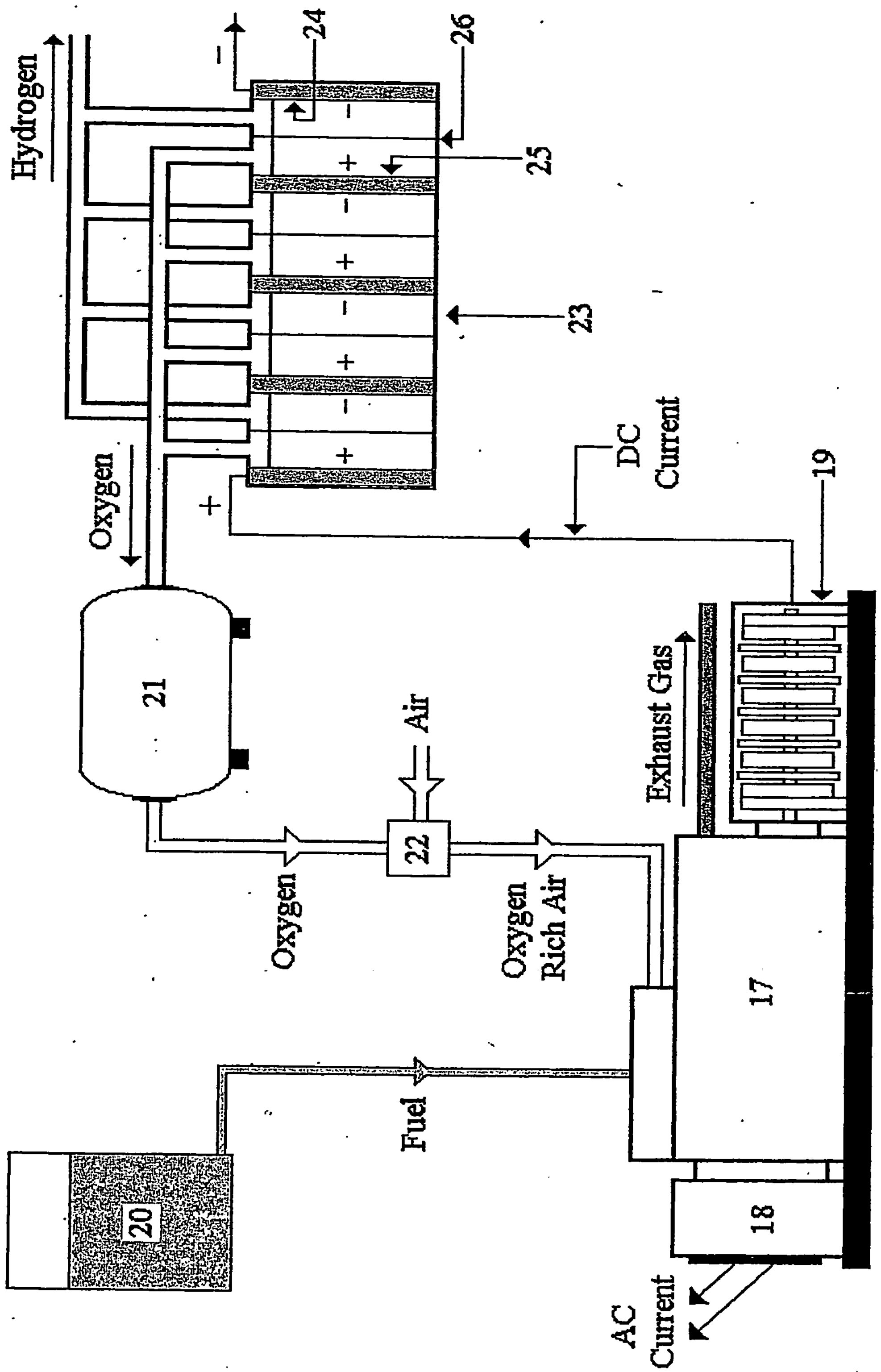
Hydrogen
Oxygen
24
26
25
23
DC Current
19
21
Air
22
Oxygen
Oxygen Rich Air
Exhaust Gas
17
Fuel
20
18
AC Current

Figure 3

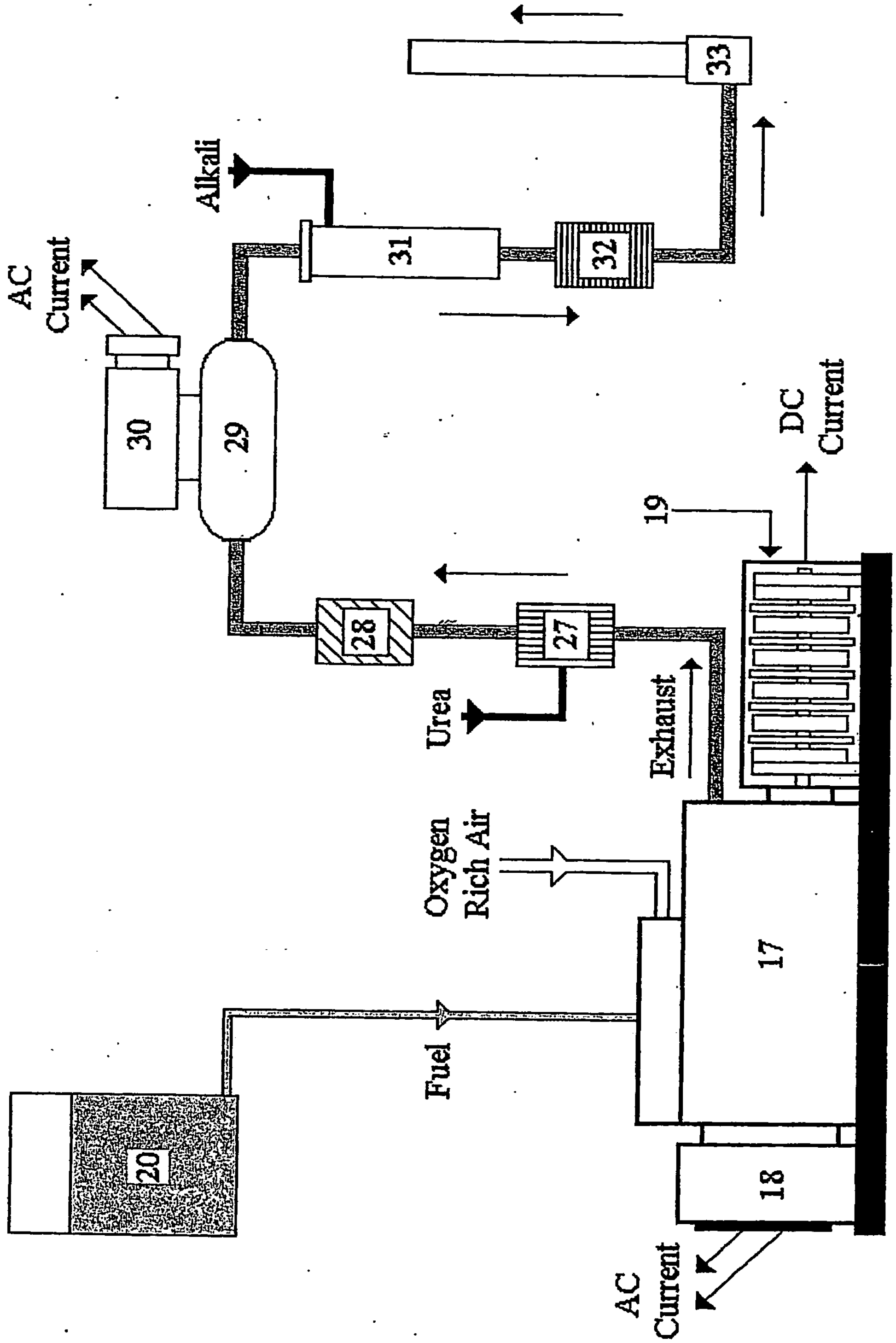
AC Current
Alkali
33
31
32
30
29
DC Current
19
28
27
Urea
Exhaust
Oxygen Rich Air
17
Fuel
20
18
AC Current

Figure 4